THE EFFECTS OF AUDITORY OR VISUAL FEEDBACK ON THE DEVELOPMENT OF CARDIOPULMONARY RESUSCITATION PSYCHOMOTOR SKILLS USING A SENSORIZED MANIKIN

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Submitted to the Graduate Faculty of

Education in partial fulfillment

of the requirements for the degree of

Doctor of Education

University of Pittsburgh

2007

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

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October 31, 2007

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Background - Cardiopulmonary resuscitation is a life skill that requires proper psychomotor skill development. It is a key component in the Concept of the “Chain of Survival. Training in CPR has been advocated since 1974 with subsequent courses and training programs. Like many programs, the curricula tend to be instructor centered, few, if any of the curricula have addressed the issue of learning styles. There is a significant amount of literature describing the lack of success in the acquisition and retention of skills. Several investigations have demonstrated that this system may improve CPR delivery and skill retention. Individuals vary in their ability to perceive, organize, store, process, understand, and use information. These differences are known as cognitive styles.

Methods - This project used an experimental design with an aptitude (learning style) treatment (feedback) interaction design. In this study two factors used in the analysis of variance. Subjects were administered the Group Embedded Figures Test to determine their level of field dependence. Groups were then randomized to receive feedback on skill performance. Following initial instruction subjects were asked to complete a three-minute bout of CPR each week for four weeks, using their assigned method of feedback. At the conclusion of the fourth week, subjects were tested without feedback.

Performance measures were rate of compressions, mean depth of compressions, percentage of correct compressions, and percentage of correct ventilations.

Results – No significant interaction was found between learning style and method of feedback for any of the variables. No main effect was noted for any of the variables and learning style. A main effect was noted for method of feedback relative to the percentage of correct compressions and the percentage of correct ventilations. Both the computer auditory and computer visual groups achieved a greater percentage of correct compressions than instructor driven feedback. For the percentage of correct ventilations, computer auditory feedback resulted in a high percentage of correct ventilations compared to instructor driven feedback.

Conclusions – Computer feedback has been demonstrated to enhance student performance, irrespective of learning style. Enhanced performance has a clinical significance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION TO THE PROBLEM

Introduction

For nearly forty years the technique of using external chest compressions with artificial ventilation has been the foundation for the resuscitation of victims experiencing cardiopulmonary arrest. In those forty years the guidelines for cardiopulmonary resuscitation (CPR) have evolved. The concept of the "Chain of Survival" which was introduced by the American Heart Association in 1991 includes the following components: 1) early access to 9-1-1; 2) early CPR; 3) early defibrillation and 4) early advanced cardiac life support (ACLS) a component in which the patient receives medications that will ameliorate his problem.

CPR is the critical means for providing through the body perfusion of blood to the heart and for circulating medications. Since CPR is so vital to survival, training the lay public in its use has been advocated since 1974. These recommendations have led to the development of both devices and courses designed to promote the learning and retention of quality CPR skills both for the lay public and professional rescuers. Recent guideline revisions have reinforced the importance of quality CPR and educational resources to address rescuer competence ("2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care," 2005).

In many educational programs, a training network is developed to educate a cadre of faculty to provide educational programs delivering content and teaching/evaluating skills. These programs have typically relied on the traditional format of lecture followed by skills demonstration that is presented either live or via video. Skill practice and evaluation become the last two components. Often, detailed checklists and performance criteria are incorporated. From an instructional design standpoint, these programs tended to be “instructor centered”, a technique, which allowed the instructor to determine the amount of time, spent on a specific topic. The courses covered a large number of topics including cardiovascular and respiratory anatomy and physiology, recognition of the signs and symptoms of heart attack and stroke, actions for survival, prudent heart living, and foreign body airway obstruction.

The literature on CPR psychomotor skill development and retention does not reveal many successful programs. A large number of studies have been conducted which evaluate these courses and their effectiveness post-course, as well as retention at three, six, and twelve months post training (Brennan & Braslow, 1995; Kaye & Mancini, 1986; Kaye et al., 1991; Wilson, Brooks, & Tweed, 1983). Much of this research has documented both poor skill acquisition post-course and poor retention of both knowledge and psychomotor skills. These findings suggest that new training methods and materials are needed. With the recent increase in microcomputer usage, along with the affordability of the systems and their technological capabilities, it seems appropriate that research be conducted on the effectiveness of incorporating these devices into CPR training.

Much of the previous literature on CPR training has documented poor performance - few have offered possible solutions. Recently a system has been developed to provide auditory and/or visual feedback to learners. Several investigations have demonstrated that the use of this system may improve CPR delivery and skill retention in a variety of populations. In these studies, a voice-assisted manikin connected to a computer assessed the learner’s performance and provided verbal feedback if the delivery of compressions and/or ventilations did not meet the pre-defined parameters. For example, when the learner delivered a chest compression that was shallow, the computer provided a voice prompt "Press Deeper." While these studies demonstrated improved overall CPR performance, they did not take into account the subjects' learning style, nor did they compare the performance based on the method of feedback provided.

Feedback

Feedback is an important component of both instructional design and the educational process. Feedback can be defined as information provided to learners about the correctness of their answers or actions (Frayer & Klausmeier, 1971). Feedback also is considered to be a critical element of providing instruction because it describes the communications or procedure given to inform a learner of the accuracy of a response (Carter, 1984; Kulhavey, 1977; Sales, 1983). 1993). Gagne (1985) describes feedback as an event of instruction following some type of practice. Proper feedback allows a learner to compare his or her performance against a standard (Johnson & Johnson, 1993).

In technology-assisted instruction, feedback is presented to the learner following an input. The purpose of this feedback is to change the perception of the learner (Sales, 1983). Forms of feedback can vary from correctness of response, the timeliness of response, and information related to precision of performance. Wagner & Wagner (1985) describe feedback as any message provided to the learner following a learner response. Kulhavey & Wagner (1993) describe the purpose of feedback in what they label as the "feedback triad" (p.5). The three components of this triad are: 1) motivation, 2) reinforcement, and 3) validation of response.

The literature on this subject is not in agreement on the correct type or amount of feedback. Smith and Ragan (1993) offer suggestions as to what types of feedback are required for various types of learning, according to Gagnes's taxonomy. A number of theorists in instructional design have suggested that different types of learning require different types of instructional strategies and techniques. However, very little emphasis has been placed on the type of correct feedback for different types of learning. Schmimel (1983) found that there are differences in the feedback required for declarative versus procedural knowledge, and what may be effective for declarative knowledge may not necessarily aid in the development of procedural knowledge.

Psychomotor skill learning involves tasks that are physical in nature and often consist of coordinated muscle movements. However, psychomotor skills also require prior cognitive knowledge. This fact is particularly true in the early developmental stages of psychomotor skills. As the learner becomes more proficient, the cognitive component becomes part of his or her subconscious.

Feedback can be provided regarding either the quality of the outcome or the process. During the early practice phase of skill development, feedback serves the function of providing information about the process of executing the motor skill. As the learner advances in his or her ability to perform the skill, feedback can focus on the process. Smith and Ragan (1993) reported that subjects learned simple motor skills when feedback was withdrawn or not given after every response. They also found better results with quantitative feedback. The literature does support that there is an appropriate time when to include feedback and at which point the feedback can be detrimental to skill development.

Visual feedback such as graphic representations can be very beneficial in a learner's psychomotor skill development. These graphic representations are sometimes called kinematics. Feedback can increase both the efficiency and the effectiveness of the learner's acquisition of psychomotor skills. In addition, feedback that is interspersed throughout the learning of motor skills is more effective than massed feedback at the end of practice (Smith & Ragan, 1993).

Augmented feedback is any form of external feedback given to a learner (Magill, 2005). There are several different types of augmented feedback, including knowledge of results, knowledge of performance, and augmented sensory feedback. Knowledge of results is external information presented about the outcome of a response (Magill, 2005). Knowledge of performance is information about performance that resulted in the outcome. Augmented sensory feedback uses an external device to supplement sensory feedback that is already available.

Augmented feedback plays multiple roles in learner acquisition of skill. The first role is to provide the learner with performance information about the success of movement in progress or movement just completed and what must be done on a future performance attempt (Magill, 2005). The second role of augmented feedback is to provide motivation to the learner. The second role is not just informational, it provides the learner with motivation to continue to develop the skill or to stop (Magill, 2005).

Augmented feedback is unique in that it may be essential, it may not be needed, in may be a hindrance, or it may enhance skill development. For some skills the feedback necessary to determine if specific actions by the learner are adequate cannot be determined by the learner, in these situations, augmented feedback is essential. In some cases of skill development, the skill itself provides sufficient sensory feedback that the leaner does not need augmented feedback. In the case of these skills, the learner can obtain the necessary information to determine if his/her actions are appropriate. For certain motor skills augmented feedback may actually hinder the development of skills by making the learner dependent upon the feedback. In these situations when the feedback is removed performance deteriorates (Magill, 2005). Finally, augmented feedback may enhance skill development. Some skills can be learned without augmented feedback; however, the skill may be learned faster or at a higher level with augmented feedback (Magill, 2005).

While prior studies have described poor CPR technique as performed by lay rescuers and among all levels of healthcare providers (Liberman, Lavoie, Mulder, & Sampalis, 1999), few potential solutions have been offered.

Recent investigations have demonstrated improvements in CPR delivery and skill retention in the lay public, paramedic student, and nurses when guided by a voice-prompting system (Handley A.J. & Handley, 2003; Hostler, Wang, Parrish, Platt, & G., 2005; Wik, Myklebust, Auestad, & Steen, 2002; Wik, Thowsen, & Steen, 2001) assessed CPR performance and provided frequent verbal feedback if the delivery of compressions or ventilations strayed beyond set performance parameters. For example, if a rescuer were delivering shallow external chest compressions, the computer would state, "press deeper." While these studies demonstrated improved aggregate CPR performance, they did not evaluate performance over time. Wik, et al., (2002) examined retention among lay rescuers.

Cognitive Styles

Cognitive styles may affect a learner's ability to learn CPR skills. Individuals vary in their ability to perceive, organize, store, process, understand, and use information (Goodenough, 1976). These differences are known as cognitive styles. Cognitive styles research is useful in identifying specific information processing differences between different student populations (Dwyer & Moore, 1991-92). A learner's cognitive style may affect his or her ability to adequately process stimuli, which may result in an unsuccessful performance. Cognitive styles are important to both educators and instructional designers for a number of reasons: they can impact learning retention and transfer; they can prevent the development of an alternative way of thinking; and they can be valuable qualities to improve (Messick, 1984). Cognitive styles have received little attention in the literature regarding CPR training and retention of skills. The cognitive style of field dependence-independence may be beneficial in evaluating a learner's ability to perform CPR properly.

A large number of cognitive styles have been identified and studied over the years. Field independence versus field dependence is probably the most well known style. It refers to a tendency to approach the environment in an analytical, as opposed to global, fashion.

The study of field dependence is concerned with the perception of upright (Asch & Witkin, 1948a, 1948b; Witkin, 1950; Witkin & Asch, 1948a, 1948b). Witkin was interested in phenomena exhibited by World War II airplane pilots who occasionally flew upside-down or sideways when they lost sight of the ground, while others maintained normal flight (Chinien & Boutin, 1992-93; Ramirez III & Castaneda, 1974). Over the years, a number of researchers investigated this phenomenon using a variety of tests including the Body Alignment Test, the Rotating Room Test, and the Rod and Frame Test. With these tests, a more general dimension of perceptual ability called field dependence was described based on external versus internal orientation (Ramirez III & Castaneda, 1974).

Additional studies linked performance on these tests with performance on other perceptual tests, specifically those that required subjects to separate a part of field from the overall field (Witkin & Goodenough, 1977, 1981; Witkin, Lewis, Hertzman, Meissner, & Wapner, 1954). Subjects who had difficulty with the Rod and Frame Test or the Body Alignment Test also had difficulty finding simple figures within a more complex design. Field dependence-independence is considered a perceptual-analytical ability.

Persons who are field dependent are more likely to follow the existing organization of a stimulus (Witkin, Goodenough, & Oltman, 1979). These persons are also more likely to exhibit a social orientation (Messick, 1976a). Field independent persons are better able to differentiate objects from embedded contexts (Messick, 1976a, 1976b) and can restructure symbolic representation to meet the requirements of a task (Witkin et al., 1979).

Field dependent individuals need to rely on the surrounding field as a frame of reference. They are typically unable to abstract an item or to solve problems that are reorganized in a different context. Instructional design and presentation strategies that impose structure on learning activities appear to benefit field dependent learners, but do not detract from field independent learners (Fleming, Knowlton, Blain, Levie, & Elerian, 1968; Grieve & Davis, 1971; Satterly & Telfer, 1979).

Learners who demonstrate strong field independence may be better able to abstract information more readily from learning materials and require fewer visual and verbal clues in order to learn effectively (Canelos, Taylor, & Dwyer, 1984).

CPR tasking is a complex skill, coupling ventilation with external chest compression. These skills could be enhanced when augmented with feedback, either from an instructor or through a computer. The ability to disembed important information also may be important for CPR instruction. Research on the interaction between feedback and field dependence-independence can provide instructors and instructional designers with the ability to maximize the performance of learners without concern for cognitive styles. Understanding individual differences of the learner could be used by instructional designers to improve instruction by accounting for these differences in the design.

Purpose of the Study

The purpose of this research study was to compare student performance on psychomotor skills of CPR relative to learning style and method of feedback. This evaluation was accomplished by examining the effectiveness of CPR performance by learners who received traditional instruction with instructor feedback, practice with audio feedback, or practice with visual feedback. Additionally, the learners were grouped according to their level of field dependence. Learners who were completing prehospital, initial or continuing education programs were taught the cognitive and psychomotor aspects of CPR using the American Heart Association standardized curriculum. Psychomotor skill development was assessed using a sensorized manikin. Participants were evaluated according to the current American Heart Association guidelines to determine their ability to perform basic life support skills in accordance with these guidelines.

Research Questions

Specific research questions that were addressed include:

1. Is there a significant interaction between a learner's degree of field dependence and skill performance using instructor driven, computer-based auditory or computer-based visual feedback?
2. Is there a main effect between instructor led, auditory and visual feedback in the performance of CPR skills?
3. Is there a main effect for levels of field dependence-independence in terms of performance of CPR skills?

Assumptions

Assumptions regarding this study include:

1. Learners will have previously participated in a lecture and an investigator provided video demonstration of CPR skills.
2. The learner's hearing and visual acuity were considered normal, and therefore, not a confounding factor in his or her performance.
3. Learners may have varied skill levels and different amounts of experience in the CPR skills.
4. Subjects are representative of healthcare and future healthcare providers, not the lay public.

Limitations

Limitations of this study included:

1. Participants were chosen from learners recruited from training programs conducted in an urban setting and the results may not necessarily generalize other populations.
2. Subjects had a limited amount of actual hands-on time with the manikin.

2. REVIEW OF THE LITERATURE

Introduction

A review of the literature demonstrates that there is significant research on field dependence-independence, CPR training, feedback, and cognitive styles. In this chapter an overview of cognitive styles followed an overview of the relevant research on CPR learning will be presented followed by a presentation of relevant literature regarding feedback and aptitude/treatment interaction. Finally, a review of the current literature on computer-driven feedback in CPR skills will be provided. Additionally, this chapter will present preliminary research conducted in preparation for this project. The chapter will conclude with an orientation of this literature to the present study.

Students enter the classroom with a variety of educational experiences and different cognitive styles, a factor, which may play a significant role in how a learner processes feedback as it relates to the development of a psychomotor skill. Cognitive styles, described as the way learners perceive, organize, process, understand, and use information (Ausburn & Ausburn, 1978; Saracho, 1989), differ dramatically across individual learners.

Cognitive styles have been described as “a family of personality traits” (Guilforn, 1980). Jonassen and Grabowski (1993) have also described these traits as “how an individual interacts with his or her environment, extracts information from it, constructs and organizes personal knowledge, and then applies that knowledge” (p. 5). It is important to note that these characteristics are related to an individual’s personality, not to his or her mental abilities

Field Dependence/Independence

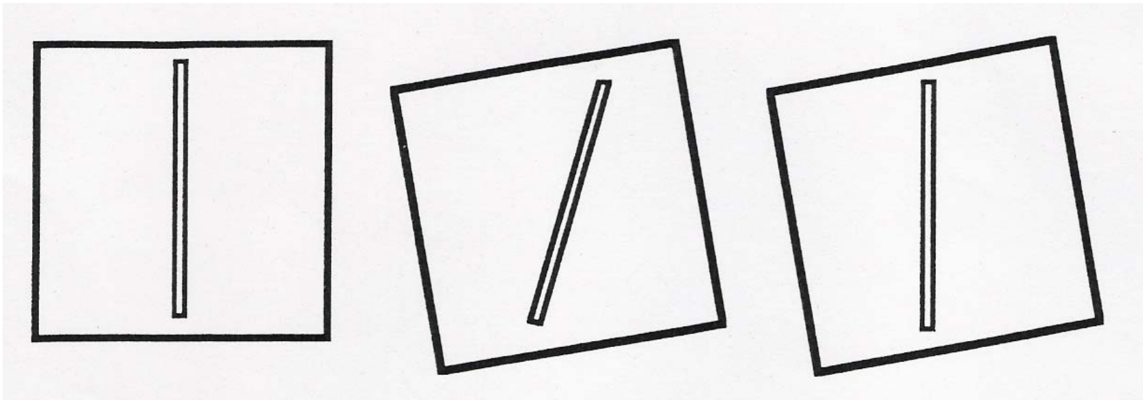
One cognitive style that has received significant consideration is the concept of field dependence. This cognitive style describes how a person relates to his or her learning environment. Specifically, it describes a learner's ability to impose structure on his or her environment.

(Goodenough & Witkin, 1977) defined cognitive style of field dependence as "the tendency to rely primarily on internal references in information process" (p. 2). Field dependence is a measure of how learners process information. This measurement has been shown to be stable over time.

Witkin is credited with early research on field dependence. He was fascinated with the finding of World War II airplane pilots who sometimes flew upside-down or sideways when they lost sight of the ground, while others maintained normal flight. His research involved both the Room Alignment Test and the Rod and Frame Test. With the Room Alignment Test, subjects were placed in a small room on a movable track. The room, their chair, or both could be tilted. Subjects were then asked to describe their room or their alignment in the room. In the second series of experiments, subjects were asked to manipulate a luminous rod surrounded by a luminous frame in a room that could be rotated. This experiment was performed in both a lighted and darkened room. These experiments led to the development of the cognitive style concept of field dependence.

In the Rod and Frame Test (RFT) the subject was placed in a darkened room and was required to adjust a luminous rod to the upright position. In this case, a luminous frame that can be rotated by the researcher frames the rod. See Figure 1 for an example of the Rod and Frame Test.

Figure 1. An example of the Rod and Frame Test



The Tilting Room/Tilting Chair (TRTC) Test involved two components, the Room Adjustment Test (RAT) and the Body Alignment Test (BAT). Subjects are placed in a chair that can be tilted right or left, in a room that can also be tilted left or right. In the first component the subject is required to move the chair until it is upright. In the second component they are required to tilt the room until it is upright (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962).

Another test for field dependence-independence is the Embedded Figures Test (EFT). The EFT was originally developed in 1971 by Witkin, Oltman, Raskin, & Karp. Since then it has been revised as a group administered version and a children's version. The Group Embedded Figures Test (GEFT) involved a subject finding a hidden simple figure and tracing it from a more complex figure. The GEFT is an adaptation of the original EFT developed by Ottman, Raskin, and Witkin. The test has been shown to be stable over time and also to correlate well with other tests of field dependence.

In the EFT subjects are shown a simple figure and are asked to find a more complex geometric design. The GEFT scoring is based on the length of time that it takes a subject to find the simple figure.

Research on CPR Learning and Retention

A large number of studies have been conducted evaluating these courses and their effectiveness post-course, as well as retention at three, six and twelve months post training (Brennan & Braslow, 1994; Kaye & Mancini, 1986; Kaye et al., 1991; Wilson et al., 1983). Much of this research has documented poor skill acquisition post-course and poor retention of both knowledge and psychomotor skills. A number of issues have been identified for this lack of success. These issues include insufficient practice time, complexity, and volume of material covered. One problem often cited was the inability of instructors to provide proper feedback and correction of skill errors (Brennan & Braslow, 1995; Kaye & Mancini, 1986; Kaye et al., 1991; Liberman et al., 1999; Wilson et al., 1983). Several studies described poor inter-rater reliability during skills practice, despite standardized checklists. To offer a solution several equipment manufacturers developed manikins with paper tape readouts and simple computer feedback used in conjunction with instructor observation. These devices have been shown to be the more objective and accurate forms of evaluation. Despite their objective nature and accuracy, these systems have not been well received because of the perceived requirement of unrealistic skill performance (Brennan, Braslow, Batcheller, & Kaye, 1996; Mancini & Kaye, 1990). Learners feel that the computer strip chart demands "perfect" CPR.

In the 1990's CPR training programs, checklists, and equipment were simplified in an attempt to make CPR training less intimidating. Along with these changes, a number of innovative instructional methods were used to improve performances and retention of the psychomotor skills. However, this improved performance is often less than optimal from a clinical standpoint. In 2000 the guidelines for CPR and Emergency

Cardiac Care (ECC) again shifted training modes to a video-based system. This model follows three basic methods: 1) passive watching, 2) learn and practice while watching, and 3) learn or practice after watching.

Passive watching provides content only. It offers an opportunity to observe cognitive knowledge and psychomotor skills. Additionally, there are some motivational attributes as well. Little information exists in the literature regarding the effectiveness of this technique; however, learners do report feeling more comfortable with the content. In the second technique, learn and practice while watching, the learner watches an instructor and attempts to follow the actions of the instructor. The third method is learn-or-practice after watching a brief video and instructor demonstration. The instructor then stops the video and allows learners to practice while he or she observes skill development. The process continues until the learners have had an adequate opportunity to learn the sequences and skills. This technique is currently used for the American Heart Association CPR courses.

Audio devices have also been successfully used to improve leaner performance during CPR classes. Audio prompting devices facilitate consistent repetitive practice, which has been demonstrated to improve initial skill development and acquisition (Milander et al., 1985). In general the use of these devices has shown an improvement in CPR skill performance.

Feedback

Computer hardware has experienced exponential growth in the last decade. Unfortunately, the same cannot be said regarding computer software. One explanation for this discrepancy is that information learned from feedback research has not been incorporated into instructional software.

Feedback is a critical element in providing instruction. Feedback helps a learner by providing “evaluative or corrective information after the student responds to a stimulus” (Carter, 1984). A review of the literature on feedback describes four characteristics of feedback. These are: function, timing, schedule, and type.

The first area, function of feedback, questions whether feedback is designed to provide information about a previous response or as a reinforcement of a correct response. Information feedback simply tells the learner if the response was correct or incorrect. Reinforcement feedback provides the learner with a positive message following a correct response. These types of feedback have been studied in several different ways by a number of researchers. Bardwell (1981) and Robin (1978) studied reinforcement feedback by comparing immediate versus delayed feedback. Gillman (1969) and Roper (1977) researched the perception of feedback as it relates to error correction and Lasoff (1981) compared two methods of phrasing the feedback. Despite the variety in methods, all of these studies produced evidence that information feedback is more effective than reinforcing feedback.

The second area of feedback literature deals with the timing of feedback. Should feedback be immediate or delayed? Immediate feedback is provided item by item with no delay. Delayed feedback can be described in three distinct ways: 1) item by item, delayed by X number of seconds (X being a predetermined number of seconds); 2) feedback provided following a sequence of items; 3) feedback provided following a sequence of items, delayed by X number of minute or hours.

Most of the literature supports delayed feedback. Sturges (1972), Rankin and Trepper (1978) described alternate ways of delaying feedback that was more effective than immediate feedback. Kulhavey and Anderson (1972) and Robin (1978) compared different ways of providing feedback, with conflicting results. Kulhavey and Anderson (1972) found that a 24-hour delay in feedback is more effective than feedback administered after a test.

The schedule of feedback is another concern. Should it be given following correct responses, incorrect responses, a specific portion of correct or incorrect, or after each response? Although delayed feedback appears to be supported, additional literature describes that the ultimate schedule of feedback is based on the complexity of material to be learners. Buss, Barden, Orgel, and Buss (1956) and Spence (1964) determined that learners engaged in discrimination tasks required feedback following errors. Anderson, Kulhavey, and Andre (1971) found differing results in learners using higher cognitive level tasks.

The type of feedback provided may also impact the learner's ability to complete the task. There are three main ways in which the learner can be provided with feedback: correct vs. incorrect, knowledge of correct, and error correction. Gilman (1969) and Roper (1977) varied feedback to learners by degree of informativeness. Subjects who received the most detailed feedback or informative feedback had better results. One area of concern as it relates to informative feedback is the risk of overwhelming the learner.

This literature provides instructional designers with important and clear messages regarding feedback. The main message is that feedback should be used to provide information only, not to reinforce or to motivate. Other messages include: a delay in the feedback will enhance performance; errors identified must be corrected; and feedback must help learners' correct errors.

Computer Driven Feedback

The voice assist approach to CPR training is a relatively new concept. Wik, Thowsen, and Steen (2001) studied twenty-three paramedic students with pervious CPR training. In this cross over study, one half of the group started with feedback, while the other half did not receive feedback. These subjects completed three minutes to CPR with no feedback followed by three minutes of CPR with audio feedback. Students who started without feedback significantly improved after feedback. The feedback to no feedback group maintained good performance during the second bout, without feedback. They concluded that this approach was a novel approach to basic CPR training caused an immediate improvement in the skill performance.

Handley and Handley (2003) further developed the work of Wik, et al. by having thirty-six nurses perform three minutes of CPR without feedback, and then randomly assigned them into auditory or no feedback groups. The group that received feedback was significantly better in performing correct CPR than the control group.

Hostler, Wang, Parish, Platt, and Guimond (2005) in a study of 114 prehospital providers found that the voice assisted manikin (VAM) system did not directly improve compression or ventilation quality; however, it did prevent a deterioration of skill over time.

Wik, Myklebust, Austad and Steen (2002), studied the retention of prehospital providers six months after training using the VAMS manikin. Using the VAMS system, initial training showed improvement in all skills. At six months, the result for the control group was not significantly different for the control groups. When verbal feedback was added to the retention test, an immediate improvement in skill performance was seen. In a similar study with 12 month retention testing, Wik, Myklebust, Auestad and Steen (2002) found similar results. There were virtually no changes in the performance of CPR skills when tested with active feedback at 12 months.

Augmented Feedback

Augmented feedback is any form of external feedback given to a learner (Magill, 2005). There are several different types of augmented feedback, including knowledge of results, knowledge of performance, and augmented sensory feedback. Knowledge of results is external information presented about the outcome of a response (Magill, 2005). Knowledge of performance is information about performance that resulted in the outcome. Augmented sensory feedback uses an external device to supplement sensory feedback that is already available.

Augmented feedback plays multiple roles in learner acquisition of skill. The first role is to provide the learner with performance information about the success of movement in progress or movement just completed and what must be done on a future performance attempt (Magill, 2005). The second role of augmented feedback is to provide motivation to the learner. The second role is not just informational, it provides the learner with motivation to continue to develop the skill or to stop (Magill, 2005).

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Aptitude Treatment Interaction

ATI research tests for a main effect (statistically significant differences between means) for the independent variables. Additionally, an analysis of variance (ANOVA) can be used to determine if interactions exist. According to Glass & Hopkins (1984) an interaction between two factors exists if the mean differences between factor A are not consistent across levels of factor B. Statistically significant interactions will appear as either an ordinal interaction where one treatment appears to be better for all learners or a disordinal interaction. Graphical representation of an ordinal interaction is depicted in figure 2. This interaction shows that treatment B is superior to treatment A.

With a disordinal interaction, the regression slopes intersect, indicating that learners with specific characteristics perform at different levels when presented with differing instructional techniques. Figure 3 presents a graphical representation of a disordinal interaction. In this example, for learners with low aptitude, treatment A was superior. For learners with high aptitude, treatment B was superior. If the overall means for treatments were calculated, there may not be a statistically significant difference between the treatment groups.

Figure 2. Graphical Representation of an Ordinal Interaction

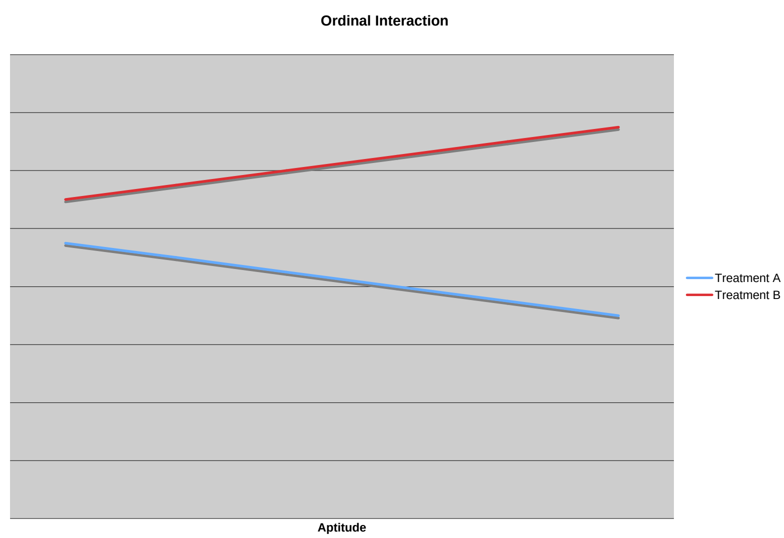
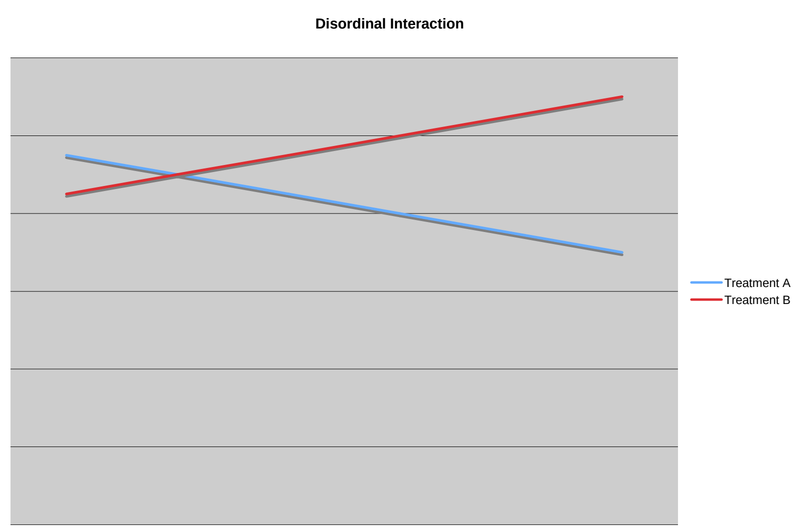


Figure 3. Graphical Representation of a Disordinal Interaction



Preliminary Research

In an effort to prepare for this study, a preliminary study was conducted to determine if voice prompting improves CPR performance by prehospital rescuers. It was hypothesized that VAM feedback would improve the delivery of chest compressions and ventilations during one-rescuer CPR.

One hundred fourteen (114) prehospital providers from one private EMS agency, two municipal EMS agencies, and one air ambulance service provided informed consent prior to beginning the study. Subjects were recruited from EMS systems within the University of Pittsburgh Medical Center command system and were not compensated for their participation. All subjects held current American Heart Association certification in Basic Life Support. All paramedic and prehospital registered nurse (PHRN) subjects held current Advanced Cardiac Life Support (ACLS) certification.

In a randomized crossover design, subjects were provided a pocket mask and instructed to perform three minutes of one-rescuer CPR on a manikin connected to a computer. They were told they would be given two minutes rest after completion and then would perform another three minutes of one-rescuer CPR. Subjects were told the computer would provide verbal advice on their performance during one of the sessions and that they should follow those instructions to the best of their ability. No other instructions were given. All subjects were naïve to the system prior to the study and were not allowed to observe other subjects being tested. When activated during the randomly assigned feedback session, the VAM software provided audible prompts in response to CPR performance outside the specified parameters and congratulated successful performance.

Resusci-Ann Modular System (RAMS) manikins connected to a PC-computer were used for this study. The voice assist manikin (VAM) software (version 1.30.19) running on a Windows 2000 platform was provided by Laerdal Medical AS (Stavanger, Norway) and has been used in previous studies of CPR performance (Handley A.J. & Handley, 2003; Wik et al., 2002; Wik et al., 2001). The software continuously assessed external chest compressions and ventilations throughout the three-minute bouts and signaled the end of a bout with an audible beep. Compression depth, compression rate, tidal volume, flow rate, and percent correct compressions and ventilations were recorded every 15 seconds by the program and exported to an Excel spreadsheet for later analysis.

The software was set to accept correct compressions and ventilations in accordance with the 2000 AHA guidelines: compression rate=100/min, compression depth=38-50mm, ventilation=700-1000 mL delivered over two seconds, and compression to ventilation ratio=15:2 (Cummins & Hazinski, 2000). Averages for demographic data were compared by t-test and ANOVA. CPR data were Generalized Estimating Equations calculated with Stata (version 8) and considered significantly different at $p \leq 0.05$.

Subjects were practicing prehospital providers certified by the Commonwealth of Pennsylvania as EMT-Basic (EMT-B), EMT-Paramedic (EMT-P), or prehospital RN (PHRN) with a mean prehospital care experience 7.8±6.9 years. EMT-B subjects were significantly younger than both the EMT-P and PHRN groups. The number of males in the EMT-P group differed from the other two groups.

VAM prompting was not directly associated with correct compressions during one-rescuer CPR in a cohort of subjects naïve to the system. However, the general decay in the fraction of correct compressions (FCC) seen over three minutes was attenuated with VAM prompting. These observations were all adjusted for order of intervention, age, sex, group and certification. The fraction of correct chest compressions (FCC) and mean compression depth (MCD) were similar at the beginning of each bout of CPR. However, values for both of these variables diverged over the three-minute period. At the beginning of CPR, the FCC was 55% for both groups. Correct compressions increased to 70% over time with VAM prompting and decreased to below 50% without. There was a slight increase in compression depth without VAM prompting and a more prominent increase when prompting was available to the rescuer. A significant VAM x time interaction increased both the fraction of correct compressions and compression and countered the negative effect of time on correct chest compressions.

In contrast, VAM prompting negatively affected the fraction of correct ventilations but attenuated the time-dependent decline in correct ventilations and ln(MTV). A decrease in correct inflations and an increase in tidal volume were noted over the course of the three-minute bouts with and without voice prompting. Time and VAM prompting had a negative effect on ventilations. VAM prompting in the first bout of CPR had a positive effect on correct ventilations and compression depth potentially indicating that corrections received initially were carried into the next bout of CPR.

In addition to VAM prompting and time, the multivariate model identified subject demographic factors as significant predictors of CPR performance. Increasing age of the subject was associated with increased correct chest compressions and ventilation tidal volume but a decreased overall fraction of correct ventilations. Female gender was associated with fewer correct ventilations and chest compressions while male subjects demonstrated increased compression depth and ventilation tidal volume. Additionally, a

VAM x gender interaction was seen in both the fraction of correct ventilations and tidal volume.

Both the urban and air medical providers were associated with higher numbers of correct chest compressions than their transport service counterparts. The air medical providers obtained higher numbers of correct inflations than the transport service providers. Certification level of the subject was less important although paramedics delivered fewer correct ventilations and smaller tidal volumes than the EMT-Basic subjects.

CPR is a task healthcare workers often perform less than optimally. Other studies using the voice assist manikin software have shown improvements in CPR skills, acquisition, retention, and performance (Handley A.J. & Handley, 2003; Wik et al., 2002; Wik et al., 2001). This study demonstrated that while VAM does not directly improve compression or ventilation rate or quality in this cohort of prehospital providers, VAM does appear to prevent decay of compression and ventilation performance over time. This is an important finding because CPR performance is known to deteriorate over time because of rescuer fatigue (Lucia et al., 1999).

One study examining fatigue during CPR followed the number of correct compressions delivered by nursing assistants during a five-minute bout (Hightower, Thomas, Stone, Dunn, & March, 1995). In that study, subjects delivered fewer than 70% correct chest compressions in the second minute and by the third minute were less than 40% effective. A subsequent study of nurses and physicians found that chest compressions were 80% correct in the first minute but less than 30% correct during subsequent minutes (Ochoa, Ramalle-Gómara, Lisa, & Saralegui, 1998). In this study, subjects performing CPR without voice feedback began the bout delivering 56.0%±35.1% correct compressions and three minutes later were only 48.9%±37.5% effective. While the wide standard deviations seen in this large group of subjects might indicate that there is considerable variation in skill level, these results are similar to a recent study examining fatigue during three-minute bouts of CPR (Ashton, McCluskey, Gwinnutt, & Keenan, 2002). In contrast, VAM feedback allowed subjects to deliver 67.7%±33.6% correct compressions at the end of the three-minute bout. None of these previous studies examining external chest compressions over time showed similar results after three minutes.

VAM prompting may improve CPR skills by guiding the subject to correct performance and correcting further performance if the skill deviates from the established standard. A benefit of VAM prompting was noted in correct inflations and compression depth for those subjects who received VAM prompting in the first bout of CPR. An earlier study of VAM feedback found subjects receiving the feedback during a three minute bout of CPR not only performed better but also maintained that level of performance in the second bout without the feedback (Wik et al., 2001). These observations suggest that a three-minute period of VAM prompting can improve psychomotor skills and that these improvements can be maintained in the short term even after VAM prompting is withdrawn.

Feedback during CPR is not without precedent. Other investigations have utilized less sophisticated prompting to improve resuscitation. Berg, Sanders, Milander, Tellez, Liu, & Beyda (1994) demonstrated that simple audio prompting during pediatric resuscitation resulted in maintenance of compression rate and improved CPR when measured by end-tidal carbon dioxide. There have also been other devices combining metronomes and depth meters to improve chest compressions during CPR (Boyle et al., 2002; Elding, Baskett, & Hughes, 1998).

In general, CPR devices have not gained widespread acceptance in prehospital resuscitation. Likewise, mechanical devices shown to be superior to manual CPR have not proliferated into the prehospital environment. Potential reasons for this lack of acceptance are prohibitive cost and the need to carry additional equipment onto a scene. It is also possible that the increment of work required by these devices prevents their acceptance. Other devices prompting CPR performance provide a continuous feedback requiring the operator's constant attention as opposed to corrective feedback applied only when performance deviates from an expected level. Recently the voice assist software has been incorporated the voice assist software into a semi-automated external defibrillator (AED). By placing the technology into a device already used during resuscitation increases its likelihood of being used, especially if it automatically activates when the device is turned on and only intrudes when a corrective action is required.

This study does have important limitations. A resuscitation manikin was used to measure CPR performance. Training and recertification required of prehospital providers requires regular demonstration of CPR on a manikin making this a non-stressful experience that may differ from actual resuscitation. Only three-minute bouts of CPR were evaluated. It is possible that longer episodes would be required during actual resuscitation. The length of the bouts was chosen to be comparable to previous studies using the VAM and was sufficient to show statistically significant differences. However, the physical demands of CPR performance make it unlikely that skill levels in a single provider will remain constant or improve over longer periods.

Verbal feedback during one rescuer CPR prevents degradation of CPR quality over three minutes in a diverse group of prehospital providers without prior exposure to the system. Future studies should examine the potential to maximize the benefit of verbal feedback on CPR performance by providing initial training and continuing education with the system.

Orientation to the Present Study

Thinking about learners' characteristics is an important part of the instructional design process, especially in the needs assessment phase. This information can be used to make decisions regarding both message design and media to improve instructional effectiveness. Without adequate research looking at these issues, instructional designers will have nothing but anecdotal evidence to make these types of decisions.

Field dependent learners have difficulty disembedding and structuring important information. These learners may expend a significant amount of cognitive effort to maintain information relative to the cognitive aspects of CPR in working memory or to impose an appropriate structure upon it. A significant amount of cognitive and psychomotor effort will be expended by learner attempting to remember the sequence of compressions and ventilations, while maintaining appropriate depth and rate of compressions. Processing effort may be consumed by remembering the sequence or the proper rate and depth of compressions, or rate and volume of ventilations.

Theory would suggest field dependent learners would most likely demonstrate a significant increase in their performance. CPR is a complex motor skill requiring specific rates and depths. By receiving auditory and visual feedback, the field dependent subject will be able to have precise feedback in a form that helps him or her impose order on an undifferentiated field.

Field independent learners will most likely have a marginal performance improvement. These learners can make sense of their world regardless of the external environment; their internal cognitive processing allows them to make sense of material.

Research studies, such as this one, are needed to examine the interaction between treatments. In this study, the difference between auditory and visual feedback, and individual differences, specifically field dependence-independence, and their impact on the development of psychomotor skills are examined. Instructional designers and educators can use these aptitude-treatment interaction (ATI) results to assist in providing appropriate feedback to learners.

3. METHODOLOGY

Introduction

Quality CPR is a cornerstone of resuscitation. In an effort to provide the best possible care for a patient learners need to be taught this fundamental skill in a manner that promotes skill development and retention. A good instructor will adapt instructional methods to accommodate differences in learners. The use of microcomputers for performance measurement and delivery of feedback may result in improved performance.

Researchers have shown that students differ in their learning styles. Additionally, how feedback is presented may also have an impact on a learner's ability to perform. Research is needed to determine if an interaction exits between these factors. In an effort to evaluate this process, this study attempted to determine of an interaction exists between two factors: the learner's cognitive style, specifically field dependence-independence, and three different methods of feedback.

Research Design

This research project used an experimental design with an aptitude by treatment interaction (ATI) design. Specifically, the study employed a prospective randomized trial of CPR skill development using three distinct methods of feedback. ATI research designs look for possible relationships between a specific aptitude or attribute variable (i.e. field dependence) and a learning outcome (CPR performance) under different instructional treatments (Snow, 1976).

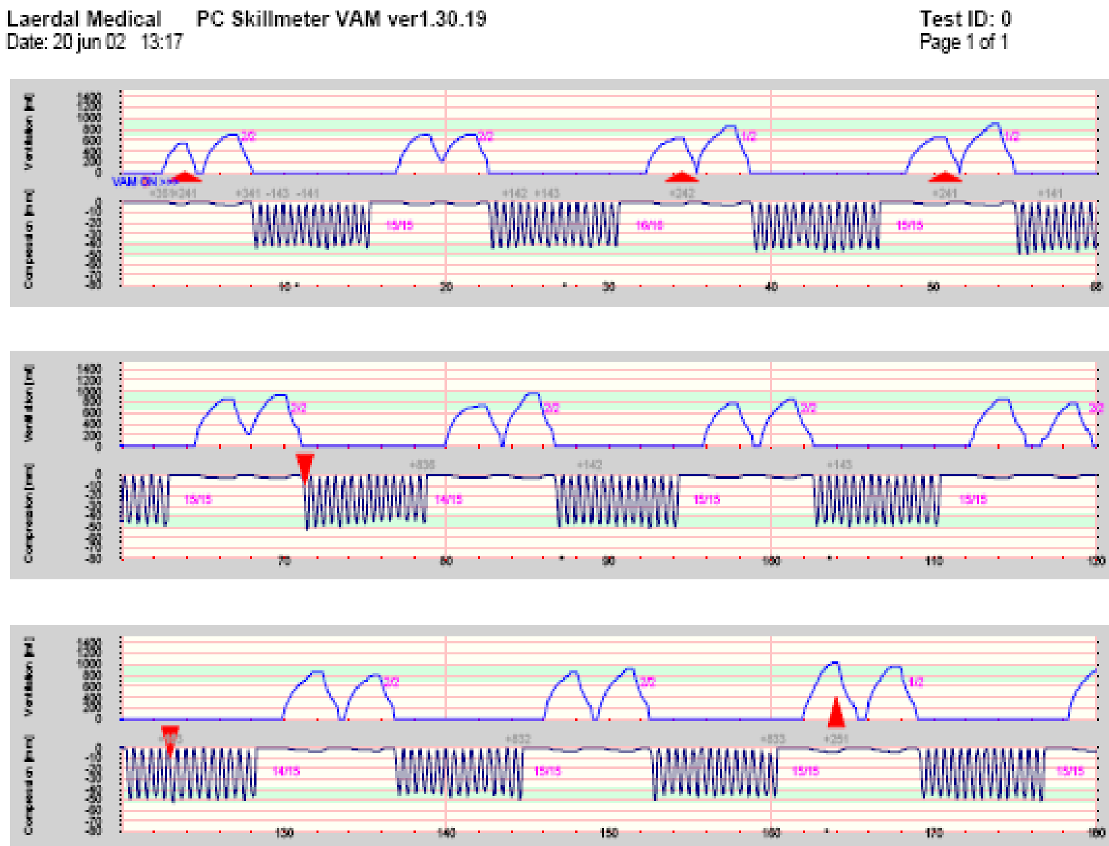
In this study, the two factors that were used in the analysis of variance were the treatments (auditory and visual) and cognitive style (level of field dependence). Learners were tested for their cognitive style based on their score on the Group Embedded Figures Test. The three groups defined using this examination are field dependent (FD), field neutral (FN), and field independent (FI). The grouping criteria established for this study is ±0.5 standard deviations from the mean. This figure is consistent with other research studies investigating field dependence-independence. Each of the subjects was assigned to a lab group based in the results of the GEFT to mirror, as closely as possible, the cognitive styles of the overall subject pool.

The lab groups were then randomized to receive instructional feedback on CPR skill performance from an instructor, from computer-driven audio prompts, or from computer-driven video prompts. Learners in each group were provided instruction in CPR using the standardized American Heart Association video. After initial training, learners were asked to complete a three-minute session of adult one rescuer CPR according to the American Heart Association Guidelines ("2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care," 2005) using their randomly assigned mode of feedback each week for four weeks. Subjects placed in the computer feedback system were naïve to the system prior to the study and were not allowed to observe other subjects during practice or testing. During the practice mode, the VAM software provided audible prompts, or visual prompts in response to CPR performance. The feedback provided included congratulatory remarks for successful performance. A summary of the audible feedback is presented in Table 1. A graphical representation of the visual feedback is presented in Figure 4.

Table 1. Summary of Feedback Presented by VAMS

Problem	Available correction phrases
Compression rate too slow	Press faster, please
	Faster
	Press a little faster
Compression rate too fast	Press slower
	Please press slower
	Press a little slower
Compression too deep	Please don't press so deep
	Don't press so deep
	Not so deep
Compression too shallow	Please press deeper
	Deeper
	Press a little deeper
	A little deeper
	Press deeper
Ventilation delivered too fast	Please blow slower
	Blow slower
Ventilation too little	More air
	Blow in more air
	Blow in more air
	Please blow in more air
Ventilation too much	A little less air
	Less air
Pause between compressions and ventilations too long	Switch faster between compressions and ventilations
Incorrect number of compressions	Press down fifteen times
Incorrect number of ventilations	Blow twice
	Blow again
	One more time
	Just blow twice
No errors in previous cycle	Great, you are doing well.
	Very good
	Wonderful
	Wonderful, do exactly what you're doing

Figure 4. Graphical Representation of Visual Feedback



Participants

Students who enrolled in emergency medical technician training at the Center for Emergency Medicine or at the University of Pittsburgh were recruited to participate in this study. The investigator provided a description of the study, allowed for questions and answers and solicited participation.

Demographics

A total of 69 subjects enrolled in the study. This sample ranged in age from 18 to 60. They were recruited without regard for race, gender, or ethnic background. The exclusion criteria was age less than 18 years; an inability to perform CPR for three minutes; or current certification as a CPR Instructor. The Institutional Review Board of the University of Pittsburgh reviewed this protocol and determined the study to be exempt. The distribution by age is presented in Table 2. A total of 40 females and 29 males initially enrolled in the study.

Table 2. Distribution by Age

Age	*N*	*Percentage*
18	2	2.9
19	29	42
20	15	21.7
21	9	13
22	3	4.3
23	3	4.3
25	1	1.4
26	3	4.3
29	1	1.4
35	1	1.4
43	1	1.4
60	1	1.4
Total	69	100

Instruments

Group Embedded Figures Test. Prior to completing the skills portion of the study, the subjects took the Group Embedded Figures Test (GEFT) to determine their level of field dependence-field independence. The GEFT is a group-administered examination, consisting of 18 items. The GEFT was designed for administration in two concurrent timed 5-minute sections. Reliability for the GEFT was reported at 0.82, which was based on correlating parallel forms of the two scored and equally timed sections of the test (Witkin, Oltman, Raskin, & Karp, 1971).

VAMS System. As previously described, VAMS is a proprietary software system for CPR research. Resusci-Ann Modular System (RAMS) manikins connected to a PC-computer were used for this study. The voice assist manikin (VAM) software (version 1.30.19) running on a Windows 2000 platform was provided by Laerdal Medical AS (Stavanger, Norway) and has been used in previous studies of CPR performance (Handley A.J. & Handley, 2003; Wik et al., 2002). The software continuously assessed external chest compressions and ventilations throughout the three-minute bouts and signaled the end of a bout with an audible beep.

The software was set to accept correct compressions and ventilations in accordance with current AHA guidelines (compression rate=100/min, compression depth=38-50mm, ventilation=700-1000 mL delivered over two seconds, and compression to ventilation ratio=15:2). Compression depth, compression rate, tidal volume, flow rate, and percent correct compressions and ventilations were recorded every 15 seconds by the program and exported to an Excel spreadsheet for later analysis.

Procedures

Students enrolled in the EMT-Basic programs offered at the Center for Emergency Medicine or at the University of Pittsburgh were given an orientation to the study by the principal investigator. As this study was determined to be exempt by the University of Pittsburgh Institutional Review Board, no consent forms were required.

Students who agreed to participate were administered the GEFT to determine their level of FD, FN, or FI. The investigator graded the GEFT. The three levels of field dependence-independence were determined by calculating the grand mean, 13.35 (range 3 – 18), and standard deviation 4.147. Subjects with a test score within 0.5 standard deviation on either side of the mean were considered to be field neutral. For this study subjects with a score greater of 11 to 15 were considered field neutral. Those subjects scoring greater than 0.5 standard deviation above the mean, for this study scores greater than or equal to 16 were classified as field independent. Any subject whose score was 0.5 standard deviation below the mean, scores less than or equal to 11, were considered to be field dependent. Following administration and scoring of the GEFT, laboratory sections were randomly assigned to one of three groups. A total of 54 subjects completed the GEFT and skill performance.

Table 3. Distribution of Subjects in the Experimental Groups

Level	Score Range	Computer Auditory	Computer Visual	Instructor Driven	Total
Field Dependent	3-11	4	3	7	14
Field Neutral	12-15	3	6	10	19
Field Independent	16-18	6	9	6	21
Total		13	18	23	54

Subjects were then asked to complete the initial training program using the assigned feedback. Subjects were also asked to complete a three-minute session of CPR using the assigned feedback each week for four weeks.

Data Tabulation

The performance of each subject was recorded by the VAM software and stored as a text file. This text file was exported to a spreadsheet for review and further analysis. The percentage of correct compressions was calculated on the spreadsheet by dividing the number of correct compressions by the number of compressions performed. The same process was used for the percentage of correct ventilations. Once the data was reviewed and the calculations made, it was exported to SPSS for analysis.

Data Analysis

Data collection began thirty seconds after the subject initiated CPR and was recorded in fifteen-second epochs. Data was collected automatically by the VAM software and was exported to SPSS version 13.0 for analysis (SPSS, Inc. Chicago, IL). Data were analyzed by analysis of variance (ANOVA) procedures. Primary terms of interest were assigned feedback and level of field dependence. Interaction terms for level of field dependence and learning type were also considered. Univariate analysis was performed identifying those with a p less than or equal to 0.05 as candidate variables for further post hoc analysis.

4. DATA ANALYSIS AND RESULTS

The primary purpose of this research was to compare student performance on the psychomotor skills of CPR relative to learning style and method of feedback. This evaluation was accomplished by examining effectiveness of CPR performance (average rate of compressions (ARC), mean compression depth (MCD), percentage of correct compressions (PCC) percentage of correct ventilations (PCV)), and by learners who received traditional instruction with instructor feedback, practice with computer based audio feedback, or practice with computer based visual feedback.

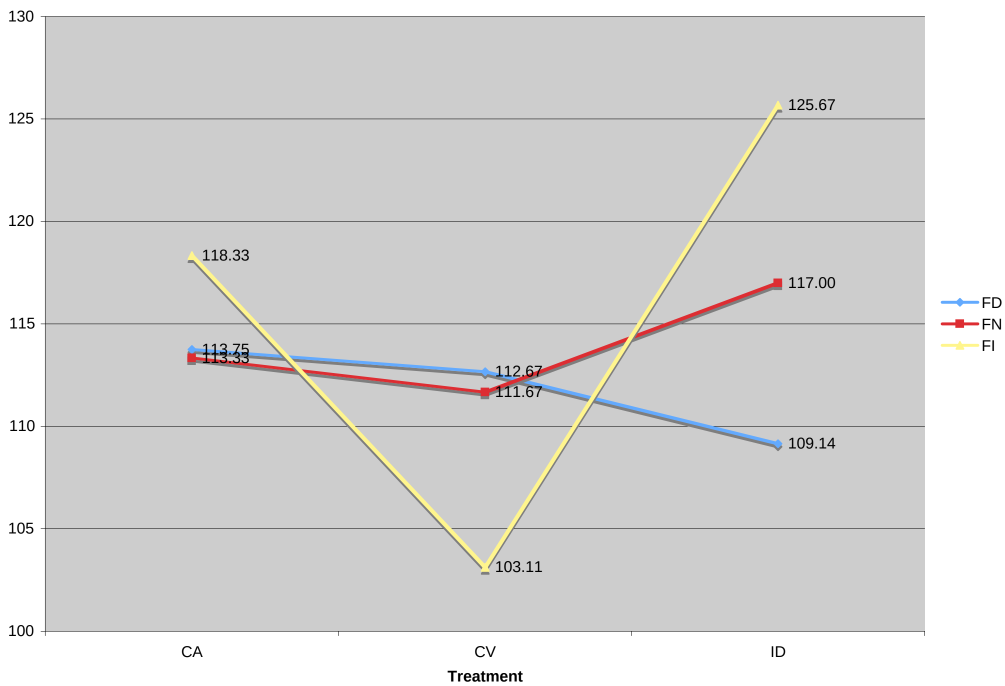
Results – Average Rate of Compressions

The posttest results are presented by achievement test, beginning with average rate of compressions (ARC). The average rate of compressions represents the average number of compressions delivered each minute. The American Heart Association Guidelines recommend a minimum of 100 compressions per minute. In this study, the mean rate of compressions overall ranged from 66 to 208 compressions per minute. Group means ranged from a low of 103.11 for field independents in the computer visual treatment to a high of 125.67 for field dependents in the computer auditory treatment. The means and standard deviations for average rate of compressions for each of the nine experimental groups are presented in Table 4. In an effort to show the relationship between groups, Figure 5 provides a line graph of the means.

Table 4. Group Means and Standard Deviations for Average Rate of Compressions

Level	Computer – Auditory			Computer - Visual			Instructor Driven			Total		
	Mean	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*
FD	113.75	3.59	4	112.67	4.16	3	109.14	15.13	7	111.21	10.77	14
FN	113.33	14.57	3	111.67	13.47	6	117.00	17.38	10	114.74	15.22	19
FI	118.33	16.11	6	103.11	19.12	9	125.67	12.77	6	113.90	18.75	21
Total	115.77	12.36	13	107.56	15.76	18	116.87	16.22	23	113.50	15.55	54

Figure 5. Line Graph of Group Means for Average Rate of Compressions by Feedback



Data Analysis– Average Rate of Compressions

To analyze the data, a two factor 3 x 3 analysis of variance (ANOVA) was used. Despite the appearance of disordinal interactions, statistical analysis with alpha set to 0.05; no statistically significant interaction was found ($F(4,45) = 1.17$, $p=0.337$) between learning style and feedback method for rate of compressions on the posttest. Additionally no main effect was found for feedback ($F(2,45) = 0.245$, $p=0.784$) or level of field dependence (F(2,45) = 1.267, p=0.292). A summary of the ANOVA is presented in Table 5.

Table 5. ANOVA Results for Rate of Compressions

Source of Variation	*SS*	*Df*	*MS*	*F*	*p value*
Feedback	114.59	2	57.30	0.245	0.784
Level of FD	593.16	2	296.58	1.267	0.292
Feedback x Level	1095.30	4	273.83	1.17	0.337
Error	10533.83	45	234.09		
Total	708453.00	54			

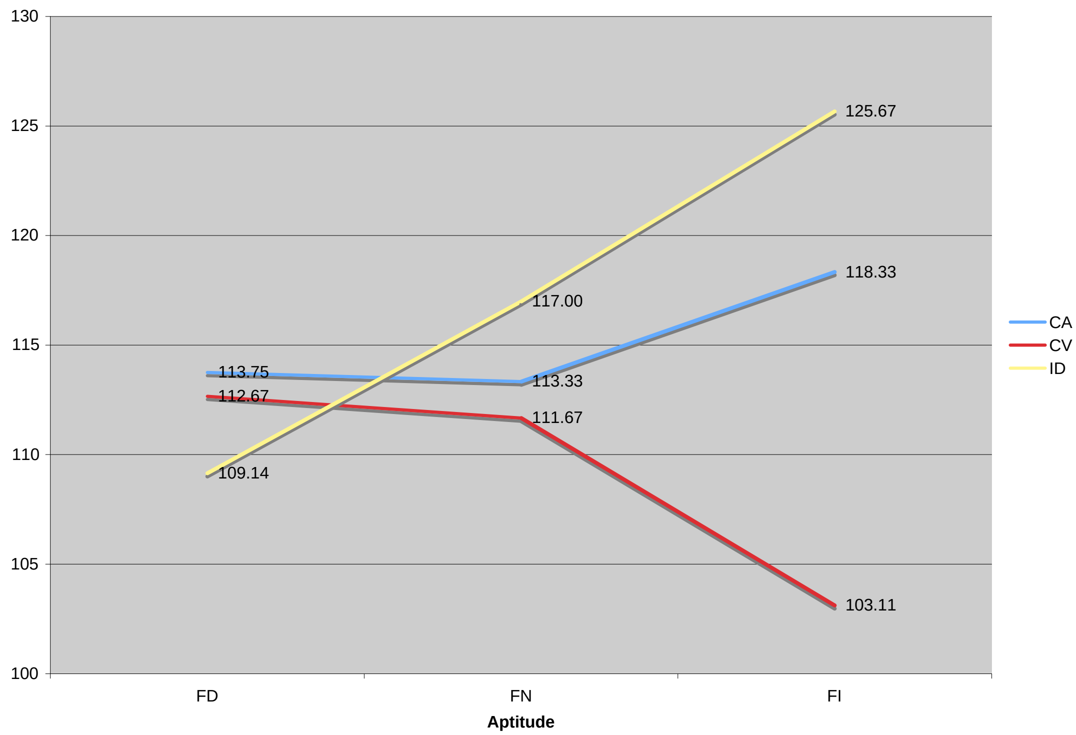
The first research question addressed in this study was: "Is there a significant interaction between a learner's degree of field dependence and skill performance for rate of compressions using instructor driven, computer-based auditory or computer-based visual feedback?"

As reported in Table 5, the ANOVA for the interaction of feedback and level of field dependence resulted on F(4,45) = 1.17, p=0.337. Therefore, there is no interaction was found between feedback and learning style for average rate of compressions in this study.

The second research question asked: "Is there a main effect between instructor led, auditory and visual feedback in the performance of CPR skills?" The ANOVA for treatments resulted in F(2,45) = 0.245, p=0.784. Interpretation of these results reveals that there is no difference in mean rate of compressions across methods of feedback in this study.

The final research question asked: "Is there a main effect for levels of field dependence-independence in terms of performance of CPR skills?" The ANOVA results for level of field depended resulted in F(2,45) = 1.267, p=0.292. This finding reveals that

Figure 6. Line Graph of Group Means for Average Rate of Compressions by Learning Style



there is no significant difference in mean rate of compression across levels of field dependence in this study.

Because this is a study of aptitude treatment interaction it is important to look at the achievement results by learning style for each of the treatments. This is graphically represented in Figure 6. The 2000 American Heart Association Guidelines recommend a rate of at least 100 compressions (Cummins & Hazinski, 2000). Looking at this graphical representation it would appear that the field dependent learners benefit from instructor driven feedback as this rate is closest to the expected outcome of 100 compressions per minute. Field neutrals demonstrated their best results with computer visual feedback. It is important to note despite the presence of an interaction on this graph, none of the results were found to be statistically significant. From a clinical standpoint it is important to note that all of these rates, being greater than 100/minute is acceptable.

Results – Mean Depth of Compressions

The second item evaluated was the mean depth of compressions. This value represents the depth (in millimeters) that the chest was compressed. The American Heart Association Guidelines recommends a depth of compressions between 38 and 50mm. In this study, the mean depth of compressions overall ranged from 20 to 54 millimeters. Group means ranged from a low of 39.33mm for field dependents in the computer visual treatment to a high of 44.11mm for field independents in the computer visual treatment. The means and standard deviations for average depth of compressions for each of the nine experimental groups are presented in Table 6. In an effort to show the relationship between groups, Figures 7 & 8 provide line graphs of the means.

Table 6. Group Means and Standard Deviations for Average Depth of Compressions

Level	Computer – Auditory			Computer – Visual			Instructor Driven			Total		
	Mean	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*
FD	40.75	8.617	4	39.333	3.786	3	43.571	8.522	7	41.857	7.502	14
FN	39.667	7.095	3	42.333	3.777	6	40.7	9.129	10	41.052	7.222	19
FI	41.833	2.994	6	44.111	3.655	9	42.167	8.681	6	42.904	5.253	21
Total	41	5.612	13	42.722	3.908	18	41.957	8.519	23	41.981	6.526	54

Data Analysis– Mean Depth of Compressions

To analyze the data, a two factor 3 x 3 analysis of variance (ANOVA) was used. Despite the appearance of disordinal interactions, statistical analysis with alpha set to 0.05; no statistically significant interaction was found ($F(4,45) = 0.313$, $p = 0.868$) between learning style and feedback method for rate of compressions on the posttest. Additionally, no main effect was found for feedback ($F(2,45) = 0.167$, $p = 0.846$) or level of field dependence ($F(2,45) = 0.345$, $p = 0.71$). A summary of the ANOVA is presented in Table 11.

Figure 7. Line Graph of Group Means for Mean Depth of Compression by Feedback

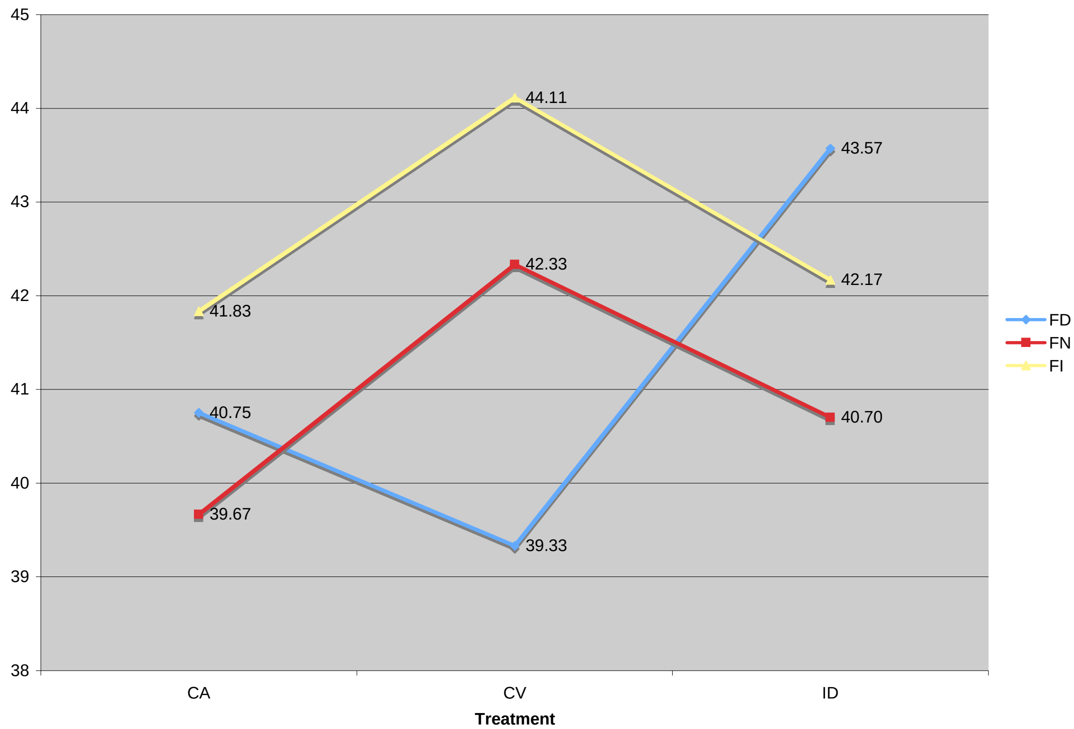


Table 7. ANOVA Results for Mean Depth of Compressions

Source of Variation	*SS*	*Df*	*MS*	*F*	*p value*
Feedback	15.89	2	7.95	0.167	0.846
Level of FD	32.76	2	16.38	0.345	0.71
Feedback x Level	59.56	4	14.89	0.313	0.868
Error	2137.79	45	47.51		
Total	97429.00	54			

The first research question addressed in this study was: "Is there a significant interaction between a learner's degree of field dependence and skill performance for depth of compressions using instructor driven, computer-based auditory or computer-based visual feedback?"

As reported in Table 7, the ANOVA for the interaction of feedback and level of field dependence resulted in $F(4,45) = 0.313$, $p = 0.868$. In other words, there is no interaction found between feedback and learning style for depth of compressions in this study.

The second research question asked: "Is there a main effect between instructor led, auditory and visual feedback in the performance of CPR skills?" The ANOVA for treatments resulted in $F(2,45) = 0.167$, $p = 0.846$. Again, with these results one can conclude that there is no difference in mean depth of compressions across methods of feedback in this study.

The final research question asked: "Is there a main effect for levels of field dependence-independence in terms of performance of CPR skills?" The ANOVA results for level of field depended resulted in $F(2,45) = 0.345$, $p = 0.71$. This finding can be interpreted that there is no significant difference in mean depth of compression across levels of field dependence in this study.

Figure 8 provides a graphical representation of the aptitude treatment interaction for the mean depth of compressions. The expected depth of compressions was 38 – 50 millimeters. All groups demonstrated the ability to meet this guideline regardless of learning style or method of feedback. Like average rate of compressions, no statistical significance was noted for any of the three learning styles or method of feedback.

Results – Percentage of Correct Compressions

The third evaluation of performance was the percentage of correct compressions (PCC). Obviously it would be desirable to achieve 100% correct on compressions; however, with human performance, this may be an unrealistic goal. A current device on the market that uses computer analysis and scoring of CPR skills uses a cut score of 70% correct to determine if a learner passes or fails. In this study, the mean percentage of

Figure 8. Line Graph for Mean Depth of Compressions by Learning Style

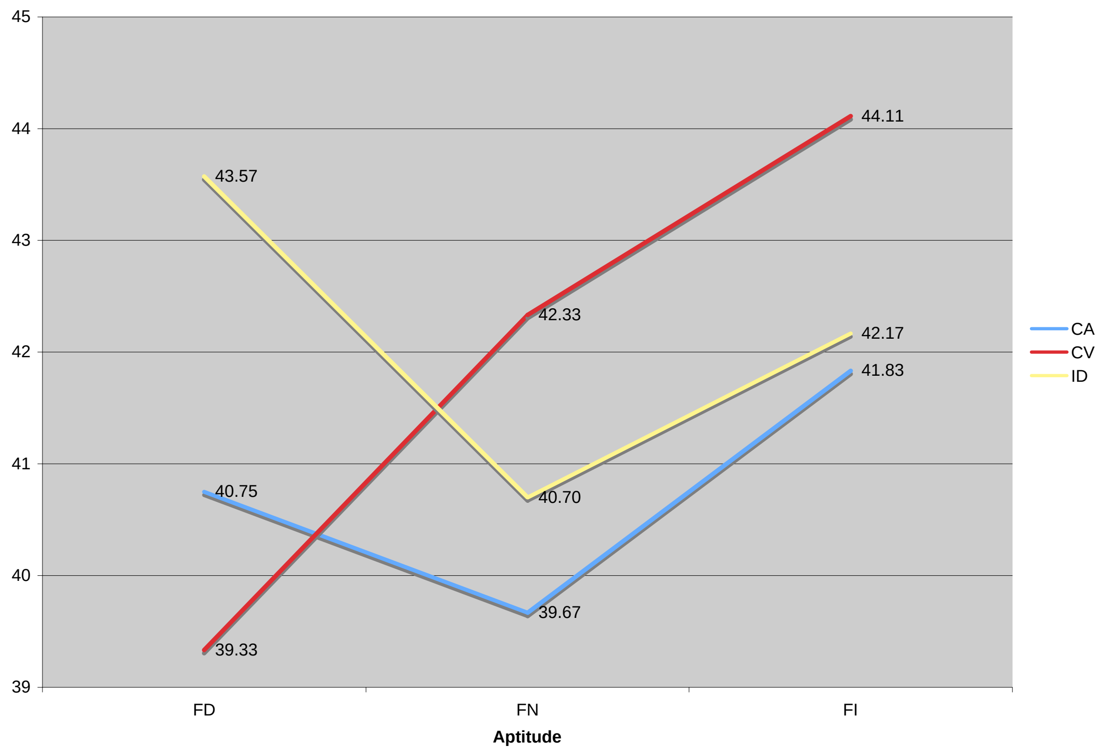
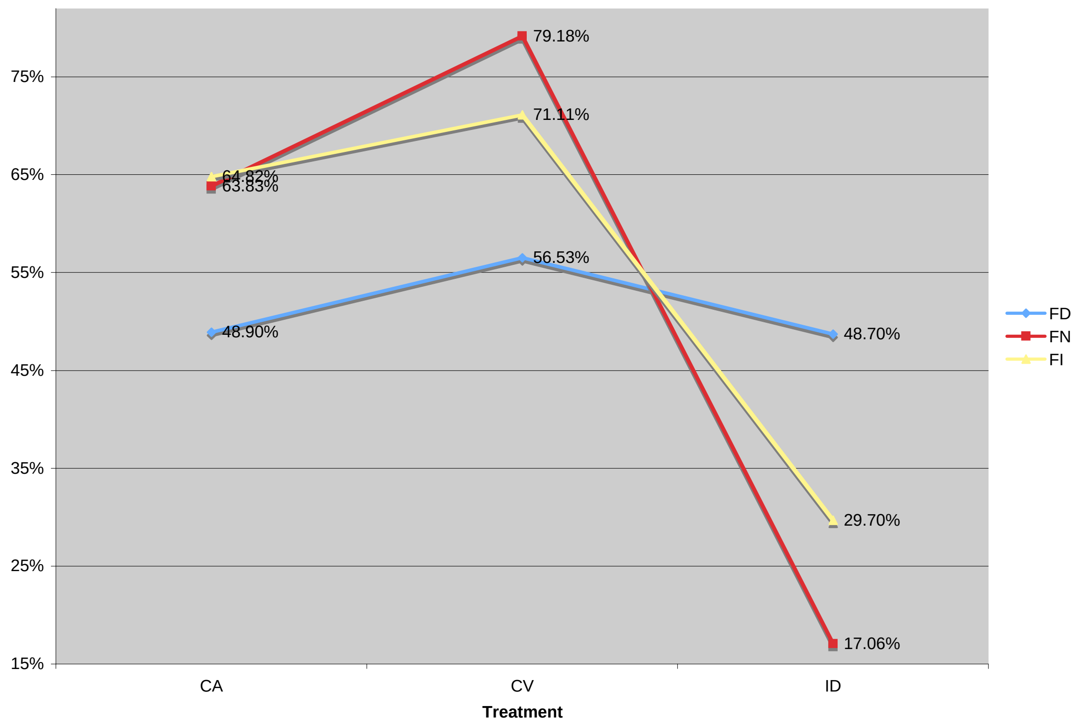


Table 8. Group Means and Standard Deviations for Percentage of Correct Compressions

Level	Computer – Auditory			Computer – Visual			Instructor Driven			Total		
	Mean	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*
FD	48.90%	39.09%	4	56.53%	26.37%	3	48.70%	42.65%	7	50.44%	36.20%	14
FN	63.83%	46.28%	3	79.18%	22.97%	6	17.06%	29.24%	10	44.06%	41.15%	19
FI	64.82%	34.90%	6	71.11%	33.77%	9	29.70%	31.98%	6	57.48%	36.71%	21
Total	59.69%	36.09%	13	71.37%	28.88%	18	29.99%	35.58%	23	50.93%	37.93%	54

correct compressions ranged from 0 to 98 percent correct. Group means ranged from a low of 17.06% for field neutrals in the instructor driven treatment to a high of 79.18% for field neutrals in the computer visual treatment. The means and standard deviations for average depth of compressions for each of the nine experimental groups are presented in Table 8. In an effort to show the relationship between groups, Figures 9 & 11 provide graphical representation of the means.

Figure 9. Line Graph of Group Means for Percentage of Correct Compressions by Feedback



Data Analysis – Percentage of Correct Compressions

To analyze the data, a two factor 3 x 3 analysis of variance (ANOVA) was used. Despite the appearance of disordinal interactions, statistical analysis with alpha set to 0.05; no statistically significant interaction was found ($F(4,45) = 0.135$, $p = 0.337$) between learning style and feedback method for percentage of correct compressions on the posttest. Additionally no main effect was found for level of field dependence ($F(2,45) = 0.05$, $p = 0.952$). However, a main effect was noted for method of feedback and mean percentage of correct compressions ($F(2,45) = 5.5886$, $p = 0.005$). A summary of the ANOVA is presented in Table 9.

To determine which method of feedback that produced the treatment effect the investigator conducted Tukey's HSD Post Hoc analysis. A statistical significance was

Table 9. ANOVA Results for Percentage of Correct Compressions

Source of Variation	*SS*	*Df*	*MS*	*F*	*p value*
Feedback	1.356	2	0.678	5.886	0.005*
Level of FD	0.0115	2	0.00572	0.05	0.952
Feedback x Level	0.539	4	0.135	1.17	0.337
Error	5.183	45	0.115		
Total	21.635	54			

*p < 0.05

Table 10. Tukey's HSD Post Hoc Analysis – Feedback Method for Percentage of Correct Compressions

Level of Comparison			*Mean Difference*	*Lower Confidence Interval*	*Upper Confidence Interval*	*p value*
CA	vs.	CV	-0.117	-0.416	0.183	0.615
CA	vs.	ID	0.297	0.012	0.583	0.040*
CV	vs.	ID	0.4139	0.155	0.673	0.001*

*p<0.05

found suggesting a main effect for both methods of computer feedback in comparison to instructor driven feedback. The results of Tukey's HSD are presented in Table 10.

The first research question addressed in this study was: "Is there a significant interaction between a learner's degree of field dependence and skill performance for percentage of correct compressions using instructor driven, computer-based auditory or computer-based visual feedback?" As reported in Table 9, the ANOVA for the interaction of feedback and level of field dependence resulted in $F(4,45) = 0.135$, $p = 0.337$. In other words, there is no interaction found between feedback and learning style for percentage of correct compressions in this study.

The second research question asked: "Is there a main effect between instructor led, auditory and visual feedback in the performance of CPR skills?" The ANOVA for treatments resulted in F(2,45) = 5.886, p=0.005, therefore it was concluded that there is a statistically significant difference in mean percentage of correct compressions across methods of feedback in this study. Further post hoc evaluation determined that both methods of computer feedback demonstrate statistically significant differences in mean percentage of compressions in this study. In both cases of computer feedback, learners had higher achievement scores for the percentage correct compressions in comparison to instructor driven feedback.

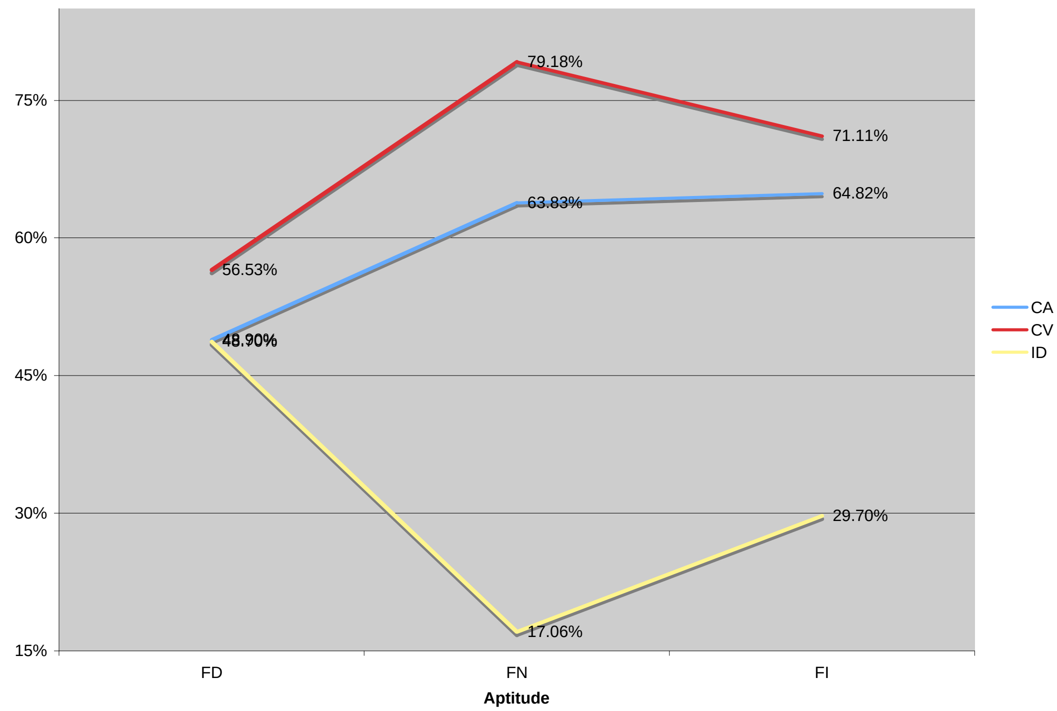
Figure 10. Post hoc analysis results for percentage of correct compressions.

CA = CV
CA > ID
CV > ID

The final research question asked: "Is there a main effect for levels of field dependence-independence in terms of performance of CPR skills?" The ANOVA results for level of field depended resulted in F(2,45) = 0.05, p = 0.952. This can be interpreted there is no significant difference in mean percentage of correct compression across levels of field dependence in this study.

Figure 11 provides a graphical representation of the aptitude by treatment interaction for percentage of correct compressions. It is expected that an achievement score for percentage of compressions should approach 100%. Looking at this figure it would appear that computer visual feedback provided the best achievement scores for all learning styles. Despite the presence of an ordinal interaction on the graphical representation, no statistical significance was detected.

Figure 11. Line Graph of Group Means for Percentage of Correct Compressions by Learning Style



Results – Percentage of Correct Ventilations

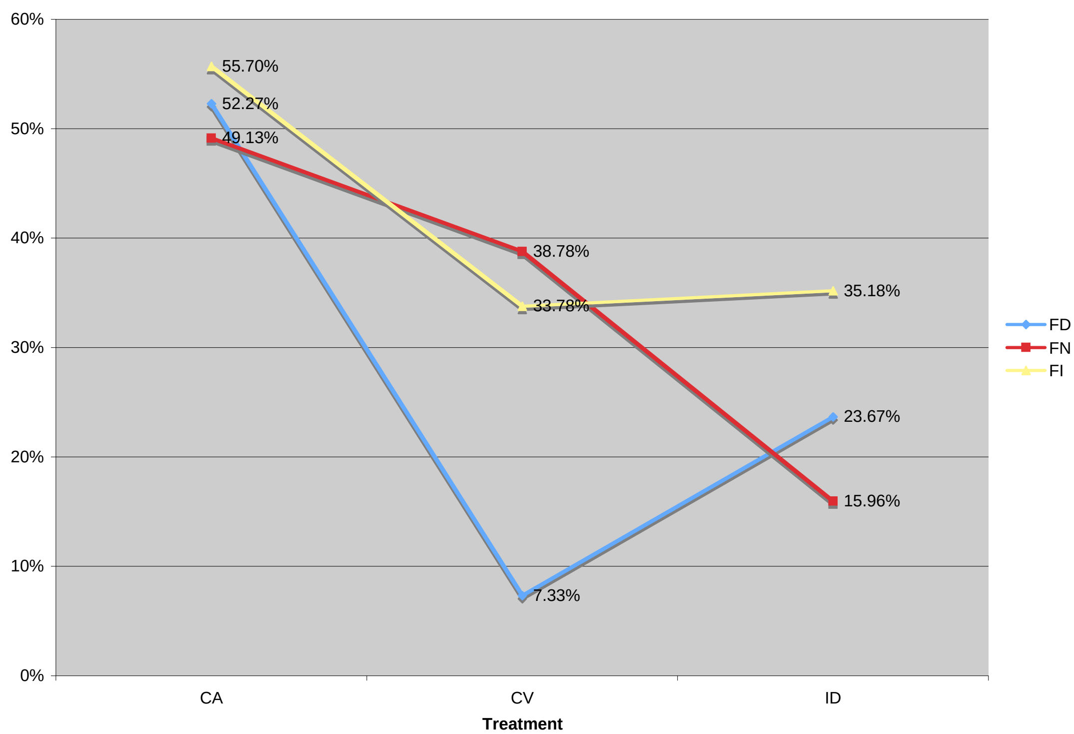
The final evaluation of performance was the percentage of correct ventilations (PCV). Like compressions, it would be desirable to achieve 100% correct on ventilation; however, with human performance, this outcome may be an unrealistic goal. A current device on the market that uses computer analysis and scoring of CPR skills uses a cut score of 70% correct to determine if a learner passes or fails. In this study, the mean percentage of correct ventilations ranged from 0 to 88 percent correct.

Group means ranged from a low of 7.33% for field dependents in the computer visual treatment to a high of 55.70% for field independents in the computer auditory treatment. The means and standard deviations for average depth of compressions for each of the nine experimental groups are presented in Table 11. In an effort to show the relationship between groups, Figures 12 & 14 provide line graphs of the means.

Table 11. Group Means and Standard Deviations for Percentage of Correct Ventilations

Level	Computer – Auditory			Computer – Visual			Instructor Driven			Total		
	Mean	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*
FD	52.27%	21.35%	4	7.33%	4.91%	3	23.67%	29.11%	7	28.34%	28.10%	14
FN	49.13%	26.87%	3	38.78%	19.29%	6	15.96%	12.54%	10	28.41%	21.35%	19
FI	55.70%	30.63%	6	33.78%	26.60%	9	35.18%	24.72%	6	40.44%	27.72%	21
Total	53.13%	25.15%	13	31.04%	23.86%	18	23.32%	22.30%	23	33.07%	25.96%	54

Figure 12. Line Graph of Group Means for Percentage of Correct Ventilations by Feedback



Data Analysis – Percentage of Correct Ventilations

To analyze the data, a two factor 3 x 3 analysis of variance (ANOVA) was used. Despite the appearance of disordinal interactions, statistical analysis with alpha set to 0.05; no statistically significant interaction was found ($F(4,45) = 1.141$, $p = 0.35$) between learning style and feedback method for percentage of correct ventilations on the post-test. The data indicate a main effect of feedback method ($F(2,45) = 5.937$, $p=0.005$) on percentage of correct ventilations.

No main effect was found for level of field dependence (F(2,45) = 1.364, p = 0.266) on percentage of correct ventilations. A summary of the ANOVA is presented in Table 12.

Table 12. ANOVA Results for Percentage of Correct Ventilations

Source of Variation	*SS*	*Df*	*MS*	*F*	*p value*
Feedback	0.65	2	0.325	5.937	0.005*
Level of FD	0.149	2	0.0746	1.364	0.266
Feedback x Level	0.25	4	0.0624	1.141	0.35
Error	2.462	45	0.0547		
Total	9.476	54			

*p < 0.05

To determine which method of feedback that produced the treatment effect the investigator conducted Tukey's HSD Post Hoc analysis. A statistical significance was found suggesting a main effect for both computer auditory feedback in comparison to computer visual and instructor driven feedback on the mean percentage of correct ventilations in this study. The results of Tukey's HSD are presented in Table 13.

Table 13. Tukey's HSD Post Hoc Analysis – Feedback Method – Percentage of Correct Ventilations

Level of Comparison		*Mean Difference*	*Lower Confidence Interval*	*Upper Confidence Interval*	*p value*
CA	CV	0.221	0.015	0.427	0.033*
CA	ID	0.298	0.101	0.495	0.002*
CV	ID	0.077	-0.101	0.256	0.551

*p<0.05

The first research question addressed in this study was: "Is there a significant interaction between a learner's degree of field dependence and skill performance for percentage of correct compressions using instructor driven, computer-based auditory or computer-based visual feedback?"

As reported in Table 12, the ANOVA for the interaction of feedback and level of field dependence resulted in $F(4,45) = 1.141$, $p = 0.35$. In other words, there is no interaction between feedback and learning style for percentage of correct ventilations in this study.

The second research question asked: "Is there a main effect between instructor led, auditory and visual feedback in the performance of CPR skills?" The ANOVA for treatments resulted in $F(2,45) = 5.937$, $p=0.005$, allowing for a conclusion that these data suggest a possible main effect for methods of feedback relative to the percentage of correct ventilations in this study. Further Post Hoc analysis using Tukey's HSD to compare mean differences across feedback methods does provides evidence of mean difference of percent of correct ventilation relative to feedback in this study. Specifically, subjects who received computer auditory feedback had statistically significant differences in their mean achievement scores for the percentage of correct ventilations. These subjects delivered a greater percentage of correct ventilations than subjects with computer visual or instructor driven feedback. These results are depicted in figure 13.

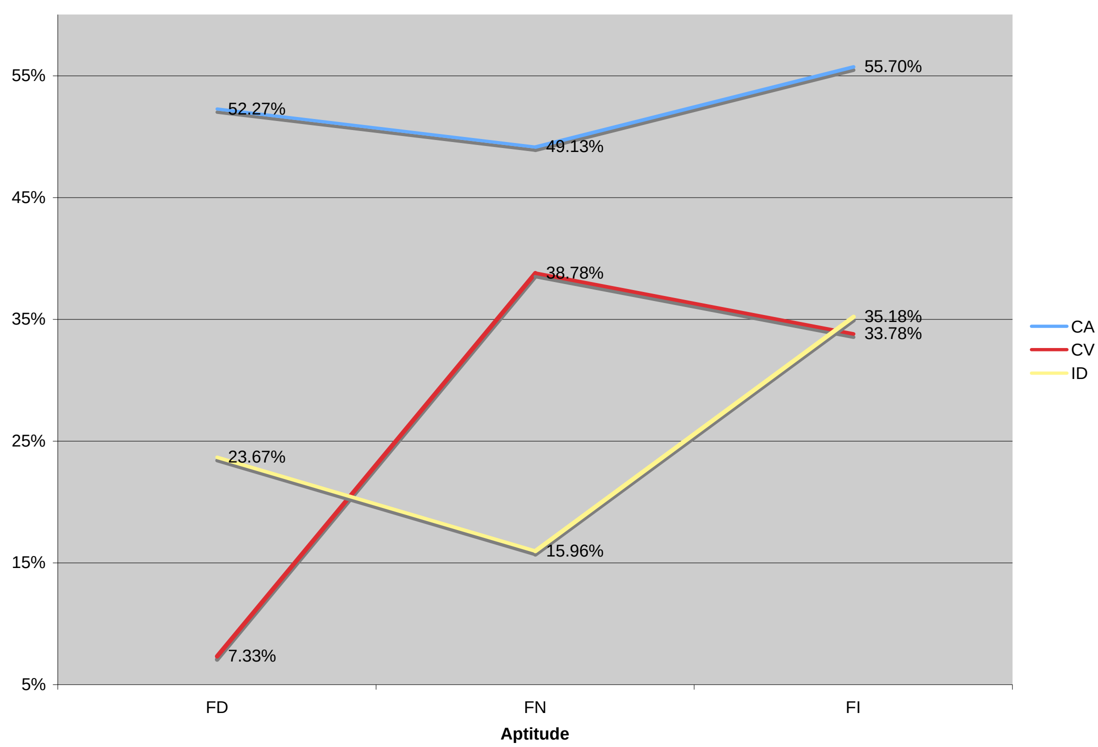
Figure 13. Graphical representation of post hoc analysis for percentage of correct ventilations.

CA > CV
CA > ID
CV = ID

The final research question asked: "Is there a main effect for levels of field dependence-independence in terms of performance of CPR skills?" The ANOVA results for level of field depended resulted in $F(2,45) = 1.1364$, $p = 0.266$. This finding can be interpreted that there is no significant difference in mean percentage of correct ventilations across levels of field dependence in this study.

The expected achievement for percentage of correct ventilations should approach 100%. Figure 14 provides a graphical representation of the achievement scores by learning style for each of the three methods of feedback. An ordinal interaction exists between computer visual and both instructor driven and computer auditory. Clearly all learners performed better when provided with auditory feedback on ventilations. Like the other four performance measures, despite the appearance of an interaction, no statistical significance was noted.

Figure 14. Line Graph of Group Means for Percentage of Correct Ventilations by Learning Style



Summary

Data analysis for each of the achievement measures did not demonstrate a statistically significant interaction for any of the performance measures. Main effects for feedback were noted for both percentage of correct compressions and percentage of correct ventilations. Further analysis of this treatment effect demonstrated further significance across the level of treatment. Post hoc identification of the level of feedback that contributed to this overall main effect for percentage of correct compressions included both computer auditory and computer visual feedback. For the percentage of correct ventilations, only computer auditory feedback contributed to the identified main effect.

5. SUMMARY, DISCUSSION, AND CONCLUSIONS

Introduction

The primary purpose of this research was to compare student performance on the psychomotor skills of CPR relative to learning style and method of feedback. This evaluation was accomplished by examining effectiveness of CPR performance (percentage of correct compressions, percentage of correct ventilations, mean compression depth, and average rate of compressions) by learners who received traditional instruction with instructor feedback, practice with computer based audio feedback, or practice with computer based visual feedback.

Sixty-nine subjects were recruited from EMT classes conducted at the Center for Emergency Medicine and the University of Pittsburgh. The subjects were administered the Group Embedded Figures Test (GEFT) to determine their level of field dependence. Based on their scores, the subjects were grouped into one of three groups, field dependent, field independent or field neutral. Each subject was randomized to receive instruction and feedback for the development of the psychomotor skills of CPR, receiving instructor driven (ID), computer assisted – auditory (CA), or computer assisted – visual (CV). Subjects were asked to complete a three-minute practice session using their assigned mode of feedback each week for four weeks. At the completion of the practical sessions, the subjects were tested on their ability to perform CPR. Fifty-four subjects completed all required practice and testing sessions.

Measurement of the percentage of correct compressions, percentage of correct ventilations, rate of compressions and depth or compressions was recorded using an adult CPR manikin and propriety software for CPR research.

Data was exported to SPSS (SPSS, Chicago, IL) for evaluation. Data was analyzed using a two-way ANOVA. For differences found at the 0.05 levels, post hoc analyses were conducted using Tukey's HSD test.

Discussion

This research project was designed using an aptitude x treatment interaction (ATI) method. ATI research can determine relationships between an aptitude or attribute and performance under varied instructional treatments. The results of this study indicated that there was no statistically significant interaction between the feedback methods, instructor driven, computer auditory, computer visual, and level of field dependence in terms of CPR performance on the selected measures. Two main effects were noted. The first was computer feedback, both auditory and visual, producing higher achievement scores for the percentage of correct compressions. The second main effect noted was an increase in the percentage of correct ventilations for subjects receiving computer – auditory feedback.

Prior to conducting this research, the investigator hypothesized that using the computer feedback field dependent learners would demonstrate a significant increase in their performance because it would impose order through precise feedback on this difficult skill. Additionally, it was suggested that there would be marginal effect on the field independent subjects. The results of this study suggest that there may not be an interaction between feedback method and level of field dependence. Although each of the graphical representations appear to show disordinal interactions, the differences in means were ultimately not found to be significant at alpha = 0.05.

In addition to the test for interaction, ATI research explores a main effect. It is important to note that with exception of average rate of compressions and mean depth of compressions, the majority of subjects failed to perform CPR correctly in terms of the percentages of correct compressions and ventilations. The notable exceptions to this finding are the field independent and field neutral learners whose mean percentage of correct compressions was 71.11% and 79.18% respectively. These results are consistent with other studies of healthcare providers' ability to perform CPR. The feedback method did, however, produce significant main effects for both percentage of correct compressions and percentage of correct ventilations.

As previously discussed, CPR is complex skill requiring cognitive processing and psychomotor skill performance. It is critical to the survival of victims of sudden cardiac arrest. This study demonstrated that, in general, computerized feedback produced better results in terms of the percentage of correct compressions and percentage of correct ventilations.

There are a number of possible reasons that this main effect was found. The precision in which a computer can measure the parameters required to perform a correct compression coupled with the processor speed of a microcomputer can provide students with immediate feedback regarding their performance. This finding is consistent with the literature on feedback, in that feedback must provide information to identify and correct errors. Additionally, the feedback must be detailed. This is an option available using the VAM software and hardware.

Although no determination could be made regarding visual versus auditory feedback, intuitively one would think that the method of visual feedback provided by the

VAM requires significant cognitive processing. The learner is required to interpret the picture and then make corrective action. With the auditory feedback, the learner can look at the manikin and feel the depth of compression or ventilation.

It is important to consider the literature on augmented feedback in reviewing this data. CPR skill development requires that the learner receive feedback on the quality of performance. It is difficult to estimate the depth of compression, especially when performing the skill on a patient as opposed to a manikin, from external sensory feedback. By providing augmented feedback the learner will know that the correct depth has been achieved. In this component of the skill, the use of augmented feedback is essential for skill acquisition.

For the development of an appropriate rate, it would appear that learners have an intrinsic ability to maintain an appropriate rate. For this component, augmented feedback may not be needed for skill development.

There are many variables that correlate to a correct compression or ventilation. These variables include rate, depth, speed of delivery, and hand position. Augmented feedback most likely is essential to the development of these skills. Whether an adequate volume of air was delivered, at the right rate cannot easily be determined through sensory feedback from the manikin model, nor from a real patient. Using augmented feedback will be beneficial in the development of both percentage of correct compressions and percentage of correct ventilations.

An area not assessed by this study, which is important for further research is whether or not the use of augmented feedback will be a hindrance to skill development.

This device has a clinical application; however if it is not widely available, learners may have poor skill performance when feedback is withdrawn.

This study does have important limitations. A resuscitation manikin was used to measure CPR performance. Training and recertification in CPR requires regular demonstration of CPR on a manikin, making this a non-stressful situation that may differ from actual resuscitation. Only three-minute bouts of CPR were evaluated. It is possible that longer episodes would be required during an actual resuscitation. The length of time was chosen to be comparable to previous studies using the VAM was sufficient to show statistically significant differences.

Participants were chosen from learners participating in an urban setting, the results might not necessarily generalize to other populations. Additionally, a subject's participation in the study may account for the observed change. The actual hands-on time with the manikin may not be representative of typical CPR courses.

Conclusions

This study found no interactions between feedback method and cognitive style. Significant main effect was identified for percentage of correct compressions and percentage of correct ventilations. Based on these results, computer feedback appears to enhance student performance in learning CPR for the percentage of correct compressions and ventilations.

The use of computer-assisted feedback has been demonstrated to enhance student performance of CPR skills with experienced healthcare providers. This study suggests that the use of computer feedback may be beneficial for skill development of novice learners as well.

These enhancements in performance also have clinical significance. The quality of CPR provided has significant bearing on the outcome of resuscitation. If students have the ability to develop strong foundational skills, it is anticipated that these will carry over into practice. By incorporating this method of feedback into the initial training of providers and into resuscitation equipment, healthcare providers and the lay public may be able to improve the quality of CPR delivered to victims of sudden cardiac arrest.

Implications and Recommendations for Future Studies

While this study has suggested that computer assisted feedback enhances the performance of CPR skills, it also implies that additional research is necessary. In addition to replication of this study to determine if similar results are obtained, suggestions for future/additional research include:

- If a computer model of feedback can be created, this study should be replicated using different subject matter to see if achievement is improved using computer-based feedback. Additionally, the subject interest in the content of the learning material should be evaluated. This difference may be a factor in the subject's motivation to perform well.
- As described in Table 4, a variety of feedback is presented to the learner. Feedback literature describes an optimal amount and type of feedback. The amount and type of feedback provided should also be evaluated.
- Studies that evaluate learners' preferences for auditory or visual feedback are also needed. This could be determined prior to assignment in experimental groups and used as a variable in the research design.

- Careful evaluation on the use of augmented feedback relative to the issue of hindrance of skill acquisition should be evaluated. Learner performance with and without feedback should be evaluated.
- Finally, as with all ATI studies, a large sample is often required before significant differences are discovered. If this study were to be replicated with a larger sample, an interaction between the treatments between field dependence – independence may be found.

Summary

Microcomputers are becoming a popular method not only for providing instruction, but also for evaluation of performance and feedback. These devices offer unique opportunities for instructional designers and learners. With opportunity comes challenge. It is important to determine how best to use this resource to achieve enhancement in student performance.

Instructional designers and educators have always tried to account for differences in learning style. This study attempted to look at this relationship to guide educators and instructional designers in the design and implementation of quality CPR education programs by determining the relationship between cognitive style and type of feedback.

In this study no significant interaction was found; however, main effects for computer-based feedback were identified for both the percentage of correct compressions and the percentage of correct ventilations. This finding suggests that use of computer feedback during the initial training in CPR may improve student performance.

Further investigation using different subject matter to see if achievement is improved using computer-based feedback, as well as the optimal amount and type of feedback is needed. Studies are also needed to evaluate the learner's preferences for auditory or visual feedback.

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